# Using Ridges and Other High Terrain

For almost all of human history, valley floors have represented the easier routes, whereas ridges, hills and mountains were generally obstacles. This was true not only for foot traffic but also for just about all vehicles—including airplanes. However, in the soaring world all this is turned around so that ridges serve as our "highways" (literally) and the intervening valleys are barriers to be crossed. This probably sounds counter-intuitive, but it is nonetheless true.

When following any highway certain rules of the road apply. This is no less true when using a ridge or other high terrain, and these rules aren't merely right-of-way or airspace conventions, for nobody can legislate the motion of the air.

**What ridges are:** ridges are often a fruitful source of orographic ("ridge") lift. High terrain is also our most powerful generator of thermals, as we'll see later.

**What ridges aren't:** you often hear that "when wind strikes a ridge, since the air has no place to go but up, there is always lift on a ridge." Alas, this isn't even close to the truth!

A much more accurate and useful way of thinking about the airflow around ridges is to remember two essential facts:

1) air has mass—therefore it has inertia
2) air has weight—therefore it takes energy to lift it

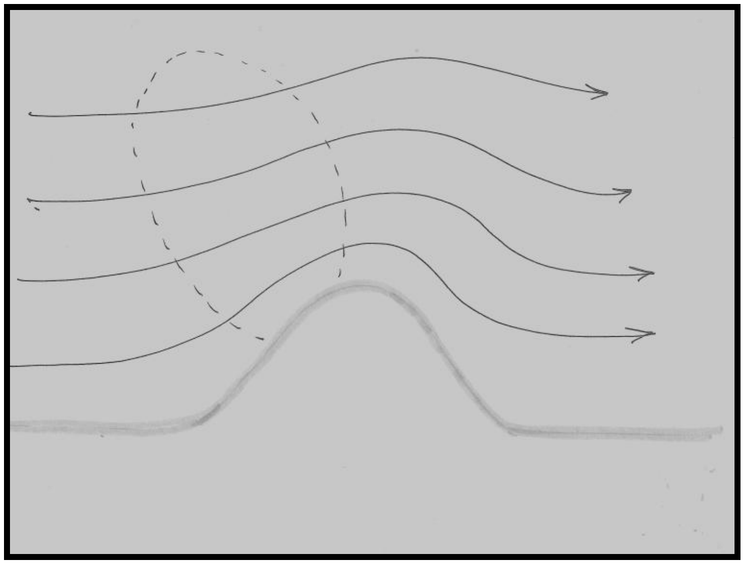
With these facts in mind, clearly a better way to explain ridge lift is that **"when air strikes a ridge, IF it has NOWHERE else to go but UP, there will be lift on the ridge—otherwise, we shouldn't count on lift being there."**

In other words, it is never wise to assume that the lift must be there!

Below are a series of rather crude sketches meant to illustrate some of the commonly-observed ramifications of the two essential facts listed above. In all cases, it is worth remembering that air would happily continue moving in the same direction and speed, and in particular would avoid climbing, unless there were no other possible paths.

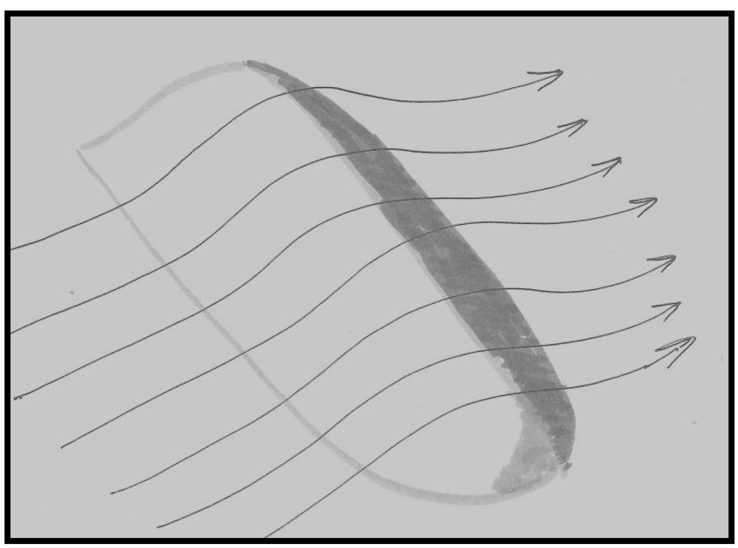
The intention here is to introduceyou to every phenomenon you are ever likely to experience while ridge soaring. In each sketch, the ridge has been depicted with a shadow on the right slope and the wind coming into the sketch from the left.

To begin with, most glider textbooks explain ridge lift with a diagram that usually looks something like this:



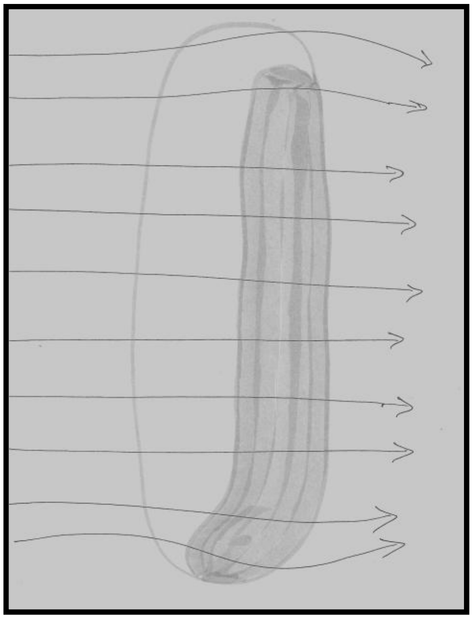
Here the wide gray line depicts the contour of the ridge, the fine dark lines represent streamlines coming from the left, and the dashed line represents the regioin of best lift helpfully drawn in by the textbook authors.

If only life were so simple! (Actually, if things were this simple, soaring would lack a lot of the charm it now has.) This simple model, while useful for "selling" the idea of ridge lift, ignores the fact that real ridges are rarely very uniform in cross section. Here's another view of the same ridge:

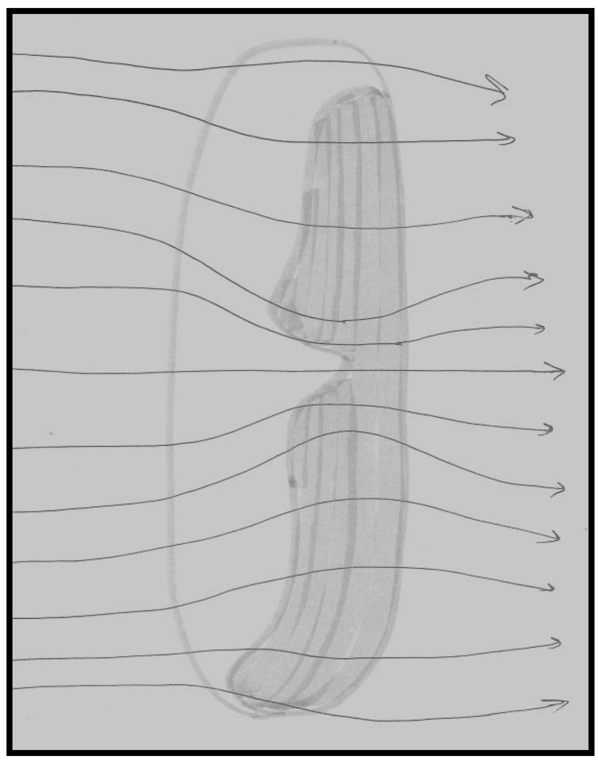


What makes this drawing so deceptive is that it neglects the fact that air will try to pass around the ridge rather than over it, and that the air always has the

opportunity to do just that at the ends of the ridge—and every ridge has at least two ends! So, seen from above, the flow over this idealized and uniform ridge would look something like this:



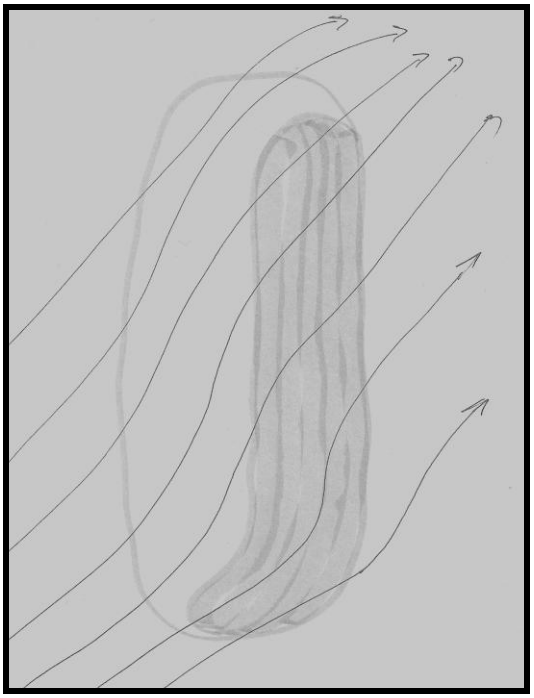
But what about irregularities sonewhere between the ends? Let's look at what that same uniform ridge might look like with a "notch" midway along it's length:



You can see here that the air turns so as to slip through the notch rather than climbing up and over the ridge. The lift is weakened or spoiled over a stretch of ridge far wider than the notch itself. This behavior can be extrapolated to cover

a wide variety of situations—for example, streamlines will split and go around both sides of an isolated knob or peak whereas a spur or bowl facing into the flow will "funnel" air up the face of the ridge and improve the lift there.

In a similar way, what about when the wind doesn't conveniently flow perpendicular to the ridge axis? In that case, the air will try to flow along the contours of the ridge rather than going up and over the top. Our picture would now look like this:

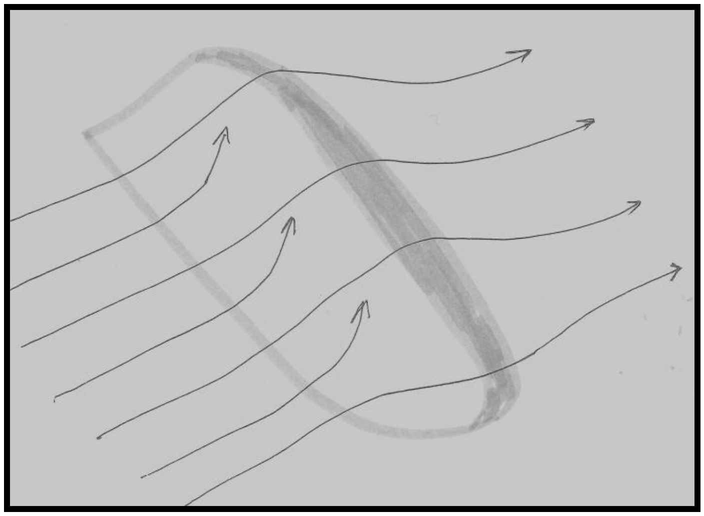


Since the air flows along the ridge, the effective slope of the ridge is decreased, thus weakening the lift we'd find there—often to the point that it becomes just about useless to us.

## Stability, Instability and Ridge Soaring

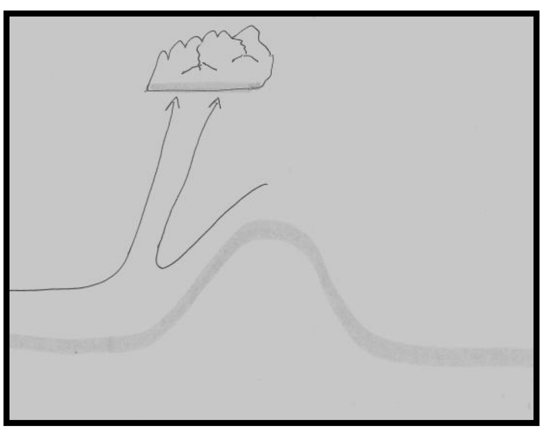
In the sketches above, a stable air mass was implicitly assumed. This is why the air didn't want to climb over the ridge but sought any way to avoid doing so—because climbing would have required doing work against the buoyancy forces present in a stable layer. A ridge is inherently destabilizing, however, because the surface is being heated as strongly as if it were located on the valley floor—yet it is much higher up, where the air is "supposed to be" cooler! **High terrain is easily our most effective thermal generator**.

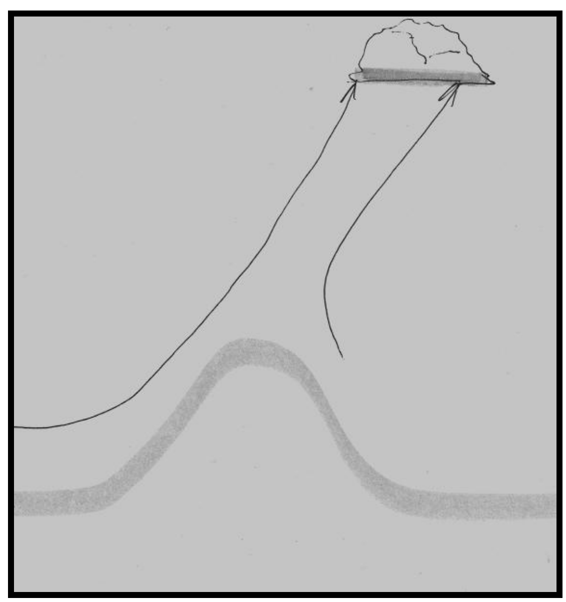
In an unstable atmosphere the picture changes: now the air wants to rise, once it begins to do so—and conversely, it wants to continue sinking once it has been started in this direction. How does this change the flow around ridges? Let's see:



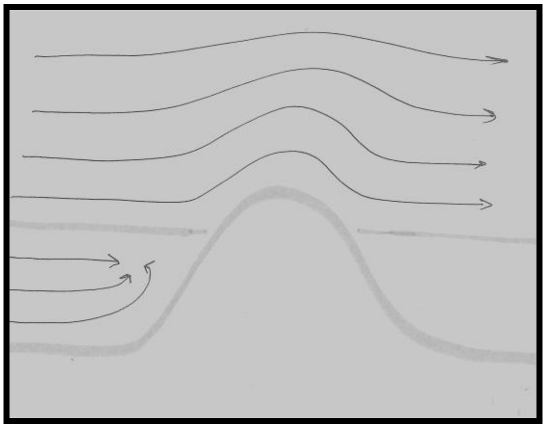
Because any instability magnifies small differences, the smooth sheet of air flowing over the ridge is broken up into thermals triggered by their encounter with the surface slope, separated by other air which is of much less interest to us!  Expect a ridge with thermals to offer a higher climb, but at the cost of a somewhat more turbulent ride.

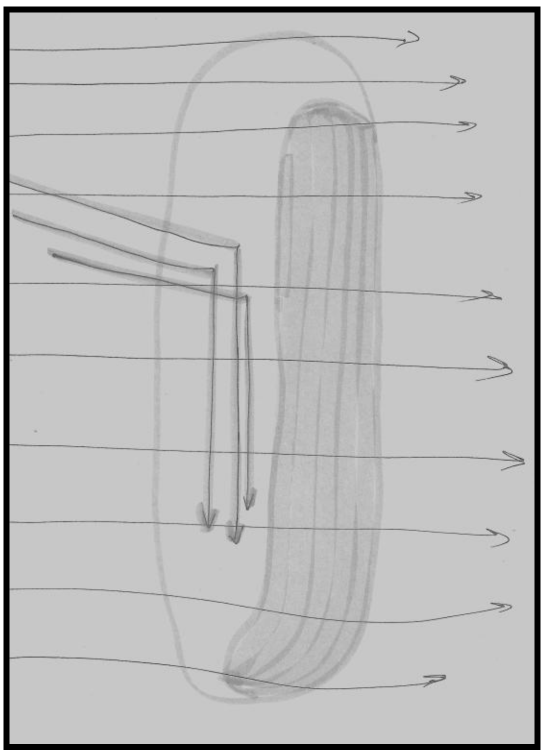
Early in the day these ridge-triggered thermals are often triggered by their encounter with the first slopes they reach—at or near the base of the ridge—as in the sketch to the left...





...while during the peak of the day these thermals will more likely have shifted to the higher slopes, as in the sketch to the right.

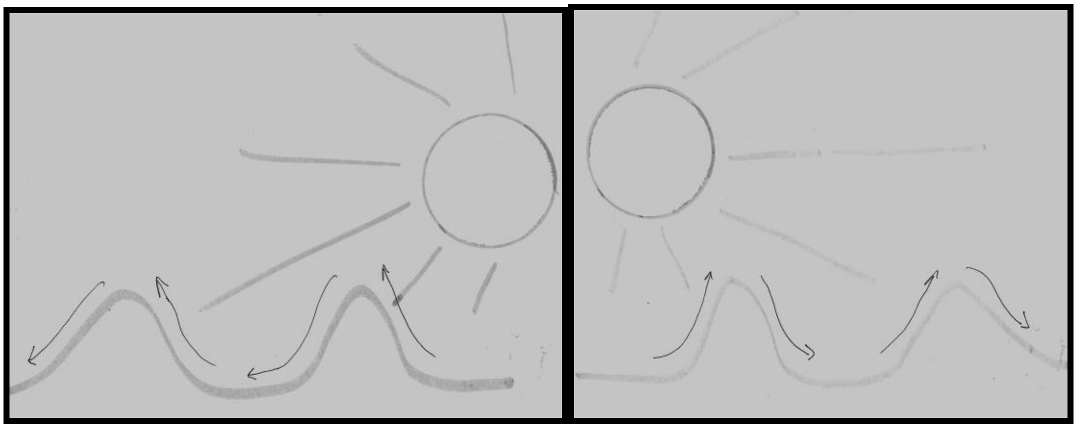




In these two sketches, a strong inversion has been depicted below the ridge crest, and the surface winds are too weak to push the air from the valley floor up over the ridge against the buoyancy forces at work in the inversion. The inversion thus forms a barrier, trapping the valley air. But that air can't simply keep piling up against the ridge; it has to go somewhere. As shown in the lower sketch that "somewhere" is along the ridge. This valley air becomes a "low level jet" which isn't very interesting to us (it provides no lift) but which could become an issue during a takeoff or landing in the valley. It would appear to a landing pilot as a low level wind shear. The air above the inversion crosses over the ridge in the way we would expect it to do. Clearly, in this situation it would pay to remain above the inversion at all times. Also it is easy to see that **just because there is good lift on the upper reaches of a ridge, we can't assume there will be lift at all levels!**

## Ridge-Induced Surface Winds

The example above, in which surface winds were modified by the presence of a ridge, serves to introduce another common interaction between ridges and surface winds. Consider the "basin and range" topography covering most of Utah and Nevada. There, the landscape features an almost endless series of parallel ridges separated by smooth valley floors. Under the action of incoming solar radiation, these parallel ridges often generate weak winds on the valley floors and adjacent slopes. These winds change during the course of the day.



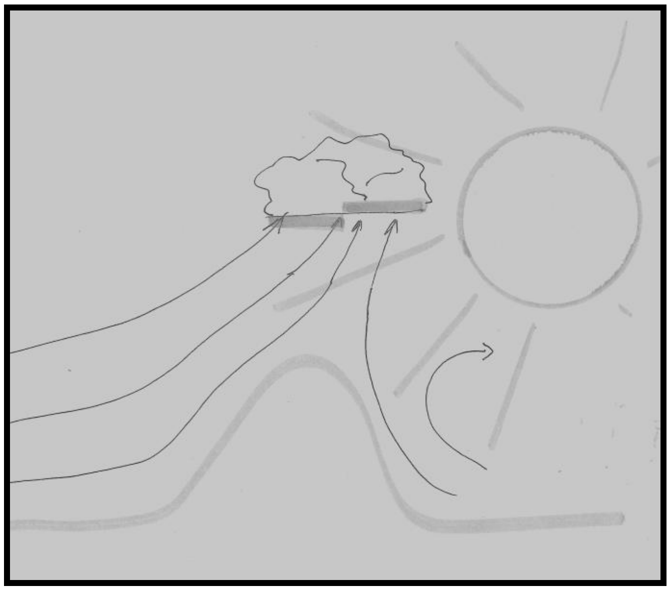
The sketch on the left shows the situation early in the day, with the direct sunlight heating up the eastern slopes of the ridges and leaving the western slopes in shadow.  The sketch on the right shows the situation in the early afternoon, with the pattern of direct insolation reversed.  The resulting surface flow on the valley floors, easterly in the morning and westerly in the afternoon, is the origin of the expression "the wind comes out of the sun."  Note that in the morning situation, with an easterly surface flow in the valley floors, is often combined with the usual westerly ("zonal") flow aloft.  One of the challenges of soaring under these conditions is successfully climbing through the resulting shear zone.

The surface flows that arise due to this effect are typically fairly shallow: sometimes as much as a couple of thousand feet deep, sometimes just a couple of wingspans in depth.  Heated air flowing up a slope because of its lowered density is known as "anabatic" flow and is a significant factor in achieving early cross-country departures in the White and Inyo Mountains on the Nevada-California border.  Anabatic flow represents a reversal of our usual mental picture:  rather than ridge lifting triggering thermals, with anabatic flow the thermals create a wnd up the slope!  Of course, this upslope wind itself will in time trigger additional thermals higher up on the slopes.  When this happens, the change is sudden and dramatic:  one moment you may be "polishing the rocks" with a landing imminent if you don't find something soon, while fifteen minutes later you're on top of the mountains at 15,000 feet and running along the mountain range at 100 kts indicated—which works out to something close to 140 kts true airspeed once density altitude is taken into account.  Impressive!

## Convergence

So much for basin-and-range country. What about the case of an isolated ridge?

Well, obviously the linkage between sun angle and surface wind isn't likely to be as significant; in fact, it isn't uncommon to find that the sun faces one side of a ridge while the wind strikes the other face. When this happens, there may be a convergence zone almost directly above the peak:



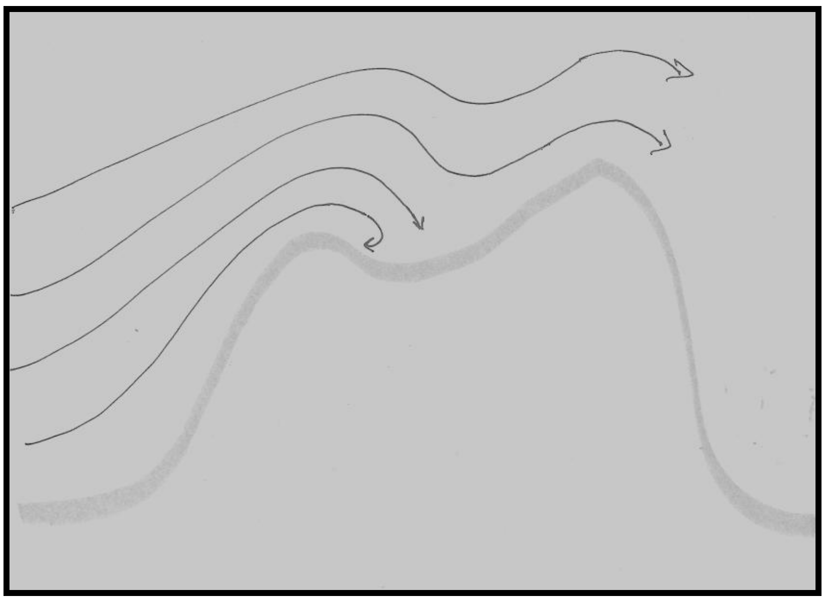
In older books on soaring, the thermal on the downwind side of the ridge was often called a "wind shadow" thermal, and there was once a lot of speculation that this thermal was somehow much stronger than typical because it has been sheltered from the wind by the ridge and thus allowed to incubate. More recently the source of this thermal's strength has been identified as simply being due to the convergence of the thermal and the ridge left. Which story is correct? Is the truth something else entirely? Nobody really knows...at least not yet.

This sketch illustrates the stepped cloud base often observed in this type of convergence zone: the airstream rising from the sunny side of the ridge is warmer and must rise higher to reach its dewpoint.

# Some hazards unique to ridge soaring

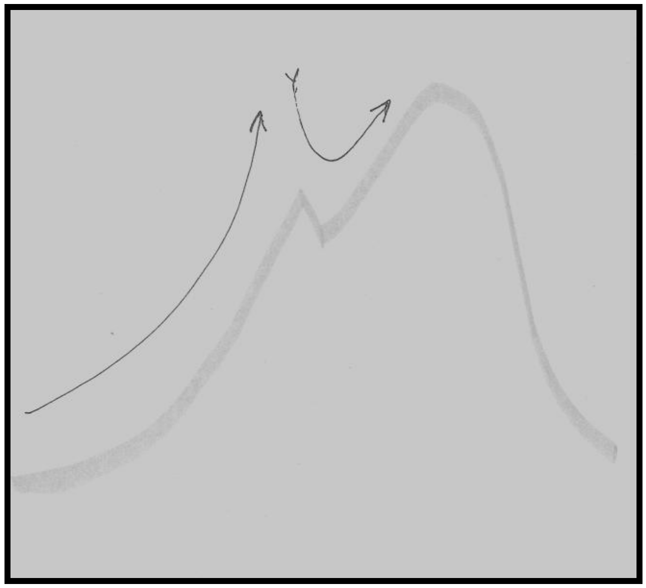
Ridge soaring, while interesting and fun, features some interesting—but not fun—hazards, too. Some are fairly intuitive; others much less so.... To begin with, something often overlooked is the midair collision risk on the ridge—and a good ridge will attract other glider pilots! In addition to watching for traffic in the usual way, try keeping an eye on your shadow as well. **No other aircraft can collide with you without your shadows merging**. The sharpness of your shadow can often provide a valuable clue to your ground clearance, too.

Here are a few other things to keep in mind when ridge soaring:

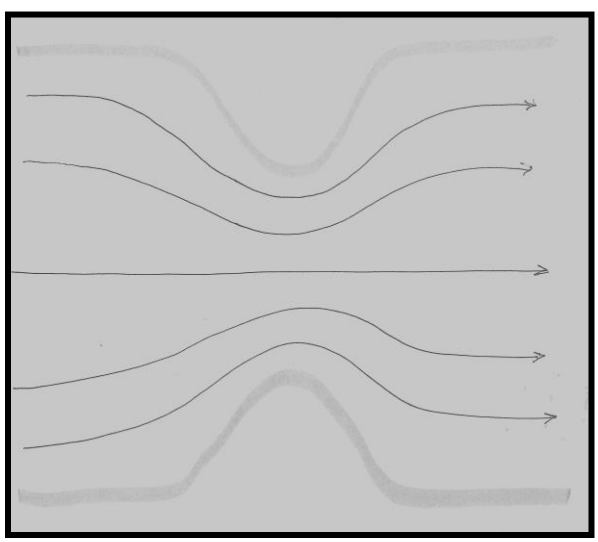


This sketch illustrates a couple of hazards: "curl" and what you might call the saddle trap. The first hazard, curl, is fairly obvious: at the toop of the ridge there is likely to be an eddy, which implies not only sink but also a significant windshear. Attempting to squeak across the ridge from the downwind side—such as after having allowed the glider to drift too far downwind with too little altitude to spare—can easily put you where you'll experience a sudden loss of airspeed just exactly where and when you can least afford it.

The second hazard is a lot more insidious. Every pilot, when first exposed to ridge soaring, is mightily impressed by the steep (and often rugged) slopes; the shallower parts of the landscape aren't so eye-catching. But imagine yourself low and slow and over the saddle to the windward side of the high ridge. Will you have enough energy to fly out of the saddle, or in other words, to escape?

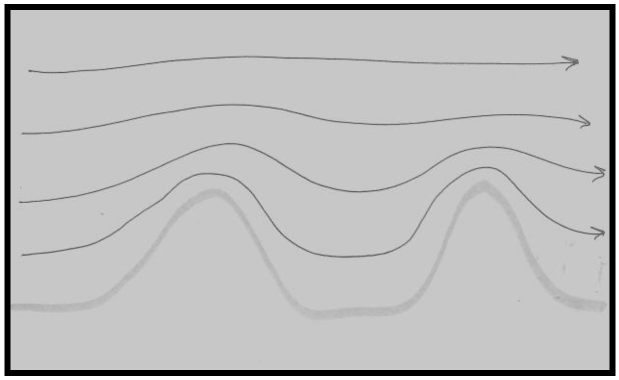


In some parts of the world, such as the White Mountains, there are lesser ridgelines below and parallel to, the main ridge axis. Above them there are occasionally very strong shears, with strong thermal lift side-by-side with equally strong downdrafts. A sailplane passing through this zone can be involuntarily rolled toward the higher terrain—a velocity difference of only 600 ft/min between the air under one wingtip and that under the other wingtip of a typical 15-meter sailplane is enough to match the power of full aileron applied at best L/D speed. The solution is to carry an additional margin of airspeed when crossing over a terrain feature such as this. Fortunately (or unfortunately) this situation is just rare enough to be commonly overlooked or disregarded by the unwary.

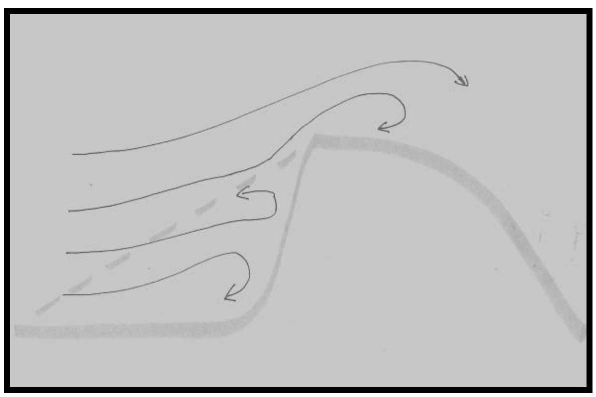


The influence of the ridge on the airflow across it decreases at higher and higher altitudes—making the flow over the ridge effectively act as one-half of the venturi depicted above. Attempting to cross the ridge at low altitude, from the

downwind side to the upwind side, will expose the pilot to increased headwinds at low altitude. The solution, if such a crossing is necessary, would be to arrive with plenty of reserve altitude and to carry plenty of extra speed as well.



Here is another aspect of the same idea: when crossing from one ridge to another upwind or downwind of it—or whenever crossing lower terrain—expect to encounter sink. As in the previous sketch, the higher you are when you begin the crossing, the less severe this effect will be. It is worth mentioning that both these situations fit nicely into the cross-country pilot's advice to "get high and stay high."



You might be tempted to think that more wind, and a steeper slope, would be conducive to better ridge soaring conditions. Up to a point this is true—but only up to a point, and that point arrives far earlier than you might think. There are very few parts of the world where ridge soaring is safe and enjoyable in winds much stronger than 25 kts or so. (In case you're curious, the ridges suitable for these conditions are relatively smooth and gentle slopes.) Excessive wind simply increases the depth of the boundary layer, and as the onrushing air flows over the resulting eddies, the effective slope of the terrain is reduced as diagrammed above. Similar results arise with an excessively steep ridge: an eddy forms at the base of the slope and the onrushing air treats this eddy as if it were part of the terrain itself.

# Exploiting Lift on the Ridge

The classic ridge soaring technique involves making repeated passes along the ridge while keeping the glider in the zone of best lift.  We must always choose a heading that allows for the downwind drift we must encounter under good ridge soaring conditions, and we must achieve this heading by making a coordinated turn.  A beginner is commonly  tempted to fly on the ridge with the uphill wing held high and the uphill rudder pedal depressed.  Don't do this!  Slipping flight is much less efficient than coordinated flight, so slipping on the ridge amounts to "soaring" with your spoilers extended...not a very good idea.

What about the correct speed to fly?  Whenever you are close enough to the terrain that a stall, or any temporary partial loss of control would result in immediate danger, you should at a minimum maintain an adequate stall margin. You should also do this whenever any other traffic is close enough that the ability to maneuver evasively is important.  In both cases, always speed up in sink, as usual.  In all other cases, however, it would be appropriate to use the most efficient ("MacCready") speed:  slow down to take advantage of lift, speed up in sink.  This is not only efficient, but safest:  using the correct speeds will maximize your separation from the terrain.

When ridge soaring our turns must always be toward lower terrain—so as to compensate for our drift while turning and also to avoid committing ourselves to a turn for which we may not have sufficient room.

When should we make these turns?  As usual in soaring, the correct short answer is "it depends."  If we are alone on the ridge, we are free to "cherry pick" the very best lift and to skip the rest.  Remember that our job as cross-country pilots—or even as future cross-country pilots—isn't to make use of ALL the lift, but rather, to make use of the BEST lift.  With this in mind, often the best place to turn around for another pass is in a patch of particularly strong lift.

A turn in sink is always very expensive.  And remember, when making a turn of more than about sixty degrees of heading change, a glider hardly covers any distance—so the altitude lost during the turn is simply wasted.  The glide ratio during such a turn is effectively zero!  So plan to turn around in good lift if at all possible.  After clearing for traffic, roll decisively into the turn, as in a thermal.

On the other hand, if we are sharing the ridge with other gliders, we are often obligated to continue each pass to the end of the lift band so as not to create an undue  hazard for the traffic behind us.  Just as with gaggling in thermals, when ridge soaring the price of sharing the lift is a significant loss of efficiency.

Suppose we are alone on the ridge, have made a number of passes, and suddenly find a patch of much stronger lift.  What should we do?  Odds are, the new lift is a passing thermal!  The best strategy is to concentrate our attention on it, temporarily (or permanently) abandoning the ridge lift.  Consider flying a series of very short passes—in effect, a series of S-turns or Figure 8s.

These S-turns will probably take you upwind, increasing your separation from the ridge, while at the same time you will be climbing in the thermal.  At some point it will become safe to begin circling in the thermal in the usual way.

How do you tell when you've reached that point?  Remember that there are basically three truly bad things that could happen to you on the ridge:

1) you might stall and collide with terrain;
2) you might encounter a gust which would cause or delay a turn;
3) you might encounter sudden strong sink.

Don't forget to include, in each of these scenarios, the risk of finding yourself low and downwind of the ridge with no safe landing site within easy reach!

The odds against any one of these things happening during any one flight, or even at any instant of your flight near the ridge, are not especially long; in other words, the chance of any one of those things happening when you wouldn't want it to happen is too significant to even considering taking the risk.

The odds against all three of these things happening at the same time are almost astronomical, so this possibility probably isn't worth factoring into your decision-making.

The odds against any two of these things happening at the same time are long, but short enough to be worth taking into account.  If you allowed for this risk you would in all likelihood be as safe as during any other phase of flight.  So, as you complete each S-turn, take a good look at the ridge and judge whether you could continue your present turn all the way "into" (towards) the high terrain, **assuming that you would during this turn suffer any two of the three possibilities**, without risk of colliding with the terrain.  If your conclusion is that such a turn would be safe, go ahead and complete the circle.  Don't forget that until you are at least several hundred feet above the highest terrain in your vicinity, you must repeat this evaluation for each circle all over again.

In summary, to exploit combined ridge and thermal lift, first fly passes, then fly S-turns, then finally spiral in thermal lift in the usual manner.  Carry extra speed, but only when close enough to terrain to be concerned for controllability; otherwise, standard speed-to-fly practice applies.  Center the yaw string, always!